STUDY OF IMPACT OF DISPERSION OF GASES FROM STACK ON ENVIRONMENT THROUGH CFD SIMULATION

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Chemical Engineering

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Under the Guidance of
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Rourkela
2015

National Institute of Technology, Rourkela

CERTIFICATE

This is to certify that the thesis entitled, **"STUDY OF IMPACT OF DISPERSION OF GASES FROM STACK ON ENVIRONMENT THROUGH CFD SIMULATION"** submitted by **Shashi shekhar** in partial fulfilments for the requirements for the award of Bachelor of Technology Degree in Chemical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date: 07-05-2015

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Date: 07-05-2015

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ABSTRACT

The main objective is to analyse the dispersion of gases emitted under different conditions of mass flow rate at the exit and ambient crossflow velocity by using software ANSYS. Main focus id to find out whether designed boiler stack can disperse atmospheric pollutants away from city or surroundings where the boiler is installed. Dispersion modelling includes means of calculating ambient ground level concentrations of emitted substances, considering the information like meteorological data, pollutants flow rates and terrain data of area. This modelling is done to assess that the Ground level concentrations (GLC) of atmospheric pollutants owing to emissions from boiler stack are less than applicable ambient air quality standards.

CONTENTS

LIST OF FIGURES

NOMENCLATURE

Δh	-	Plume rise (m)
F	-	Buoyancy Flux
u	-	Average wind speed (m/s)
x	-	Downwind distance from stack (m)
g	-	Acceleration due to gravity (m/s^2)
v	-	Volumetric flow rate (m^3/hr)
T_s	-	Temperature of stack gas (k)
T_g	-	Temperature of ambient air (k)
X	-	Ground level pollutant concentration
Q	-	Mass emitted per unit time (g/s)
u	-	Wind speed (m/s)
y	-	Distance in horizontal direction (m)
z	-	Distance in vertical direction (m)
H	-	Effective stack height (m)

CHAPTER 1
INTRODUCTION

1.1 AIR POLLUTION

Air pollutants are introduced in the surrounding from the variety of sources that changes the composition of the atmosphere and affect the living species of environment. The concentration of the air pollutants depend not only on the quantities which are emitted from pollution sources but also depends upon the ability of the atmosphere to either absorb or disperse these pollutants. The concentration of air pollutants vary spatially and temporarily causing the air pollution to change with different positions and time due to changes in meteorological and topographical condition. The sources of air pollutants are automobiles, industries, domestic sources and natural sources. Due the presence of high amount of air pollutants in the air, the health of the people and the property is getting adversely affected. In order to capture the deterioration in air quality, Govt. of India has approved Air (Prevention and Control of Pollution) Act in 1981. This responsibility has been further improved under Environment (Protection) Act, 1986. It is important to evaluate the present and expected air contamination through constant air quality overview/observing projects. In this manner, Central Pollution Control Board had begun National Ambient Air Quality Monitoring (NAAQM) Network amid 1984 - 85 at national level. The project was later renamed as National Air Quality Monitoring Program (NAMP). The ambient air quality monitoring observing system includes estimation of various air contaminations at number of areas in the nation to meet targets of the checking Air quality checking system additionally includes choice of poisons, determination of areas, fixation and the kind of toxins in the environment through different normal sources, called regular urban air toxins, for example, Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM), Sulfur dioxide (SO2), Oxides of Nitrogen (NOx), and Carbon Monoxide (CO) and so on .

1.2 AIR (PREVENTION AND CONTROL OF POLLUTION) ACT 1981

Administration of India made the law of Air (Prevention and Control of Pollution) Act 1981 to compute the deterioration in the air quality all around. The act prescribes different capacities for the Central Pollution Control Board (CPCB) at the peak level and State Pollution Control Boards at the state level.

1.3 NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

The targets/gauges of ambient air quality are essential for creating project for compelling administration of surrounding air quality and to lessen the harming impacts of air contamination. The goals of air quality measures are: -

- To show the levels of air quality essential with a sufficient margin of safety to protect the public health, vegetation and property.
- To aid in creating needs for reduction and control of pollutant level.
- To give uniform measuring stick for evaluating air quality at national level.

1.4 COMPUTATIONAL FLUID DYNAMICS

It is normally abbreviated as CFD and is characterized as a branch of fluid mechanics that solves and analyses fluid flow issues, utilizing numerical techniques and calculations. In order to perform the calculations required to simulate the fluid-surface interaction, characterized by boundary conditions, computers need to be utilized. Advantage in utilizing high-speed supercomputers is that it provides better solutions.

1.5 ANSYS, INC.

It is an engineering simulation software (computer-aided engineering, or simply CAE in short) developer that is headquartered in Canonsburg, Pennsylvania, United States. The company was founded in 1970 by Dr. John A. Swanson and was originally named **Swanson Analysis Systems, Inc**. ANSYS offers a comprehensive range of engineering simulation solution sets providing access to virtually any field of engineering simulation that a design process requires :-

- **Simulation Technology** Structural Mechanics Multiphysics Fluid Dynamics Explicit Dynamics Electromagnetics.

- **Workflow Technology** ANSYS Workbench Platform High-Performance Computing Geometry Interfaces Simulation Process & Data Management.

The present project work utilizes ANSYS 15.0 where Workbench is used for the geometry purpose while the further simulation is done using Fluent 6.2.16. The mass fraction of different gases and pressure profiles are observed at different velocities of the wind and at different velocities of the gases coming out from stack. The mass fraction for different gases at different distances along the horizontally and as well as vertically are obtained and are checked with ambient condition.

CHAPTER 2
LITERATURE REVIEW

2.1 OVERVIEW

For over 40 years the American Institute of Chemical Engineers (AIChE) is involved in process safety and loss prevention for the chemical, petrochemical, oil and gas related industries and facilities. The publications of AIChE are information resources for the chemical engineering and other professions on the causes of industrial incidents and the also preventing their occurrences and mitigating their consequences. The Centre for Chemical Process Safety (CCPS), in 1985 the directorate of AICHE was established to organise and disseminate the information for use of promoting the safe operation of chemical industrial operations and facilities and the prevention of chemical process incidents. With the help and direction of its advisory and management boards, CCPS established a multifaceted program to address the need for risk and safety technology and management systems to reduce risks to the public, the environment, personnel and facilities.

Under the U.S. regulations it is necessary to calculate the potential concentrations of hazardous or flammable substances in the surroundings as part of health, safety and environmental assessments at and near industrial areas. For example, these calculations can be used in real-time hazard calculation, or may be part of submittals to regulatory agencies. The calculations are required for regular emissions, such as emissions from stacks from combustion of fuel, as well as for accidental emissions. These problems are addressed using species transport and dispersion models, which needs a variety of meteorological inputs, also including boundary layer scaling parameters which is surface roughness length, displacement length, d, friction velocity, $u*$ and Monin–Obukhov length, L. The parameters such as the surface roughness length which needs to be described and methods are generated to estimate that parameter from readily available information such as site plans of industrial plants. It is important to evaluate the site roughness because the maximum GLC for near-ground releases tends to decrease by about a factor of two for each order of magnitude increase in surface roughness length, zo.

Generally all systems available for dispersion calculations assume that the depth of vapor cloud is generally greater than the height of nearby obstacles and buildings. The releases which are near and within an industrial area, this is unlikely to always be the case. The appropriateness of existing models for application to industrial facilities must be objectively assessed. For many actual scenarios, models do not currently exist. We have developed within this book a number of novel approaches that may be useful to dispersion calculations in The plume dispersion behaviour is intended to be consistent with similar sections in other CCPS books, some of them are Lantzy, DeVaull, King, and Fontaine (1995) and Hanna, Chang and Drivas (1996). Dispersion needs basic meteorological concepts and describes how the average obstacle height (Hr), the surface roughness length (zo), and the displacement length (d), are required in the calculation of atmospheric transport and dispersion. The terms related to dispersion are also explained in standard atmospheric boundary layer textbooks such as Stull (1997) and Garratt (1992) and in standard atmospheric dispersion textbooks such as Smith (1983), Hanna, Briggs and Hosker (1982), and Pasquill and Arya (1999).

2.2 STACK DESIGN

Pollutants are thrown into the atmosphere in a number of different ways. For example wind dust is blown off into the air by the wind. When any plant material decays, methane is released. Pollutants are emitted by the Automobiles, trucks and buses engine exhausts and during refuelling. Electric power plants and home furnaces emits pollutants as they are tried to satisfy mankind's need for energy. One method of releasing the pollution has received more attention than any other ─pollution released from stationary point sources, i.e. stacks. Stacks used to come in all sizes ─for a small vent on a building's roof to a tall stack. Their function is to release the pollutants high enough above the earth's surface so that the emitted pollutants can effectively disperse in the atmosphere before coming to the ground level. All else being equal, taller stacks disperse the pollutants better than the shorter stacks because the plume has to travel through a greater depth of the atmosphere before it reaches to the ground level. As the plume travels it disperse and spreads.

2.3 PLUME DISPERSION

Gases which are emitted from stacks are generally pushed out by fans. As these turbulent exhaust gases comes out from the stack they mix with ambient air. This mixing of ambient air inside the plume is called **entrainment**. As the air is entrained into the plume, the plume diameter grows wider as it travels downwind. These exhaust gases are having momentum as they enter into the atmosphere. Moreover these gases are heated and are warmer than the surroundings air. In such cases the emitted gases are less dense than the surroundings air and are therefore buoyant. A combination of the exhaust gases' momentum and buoyancy causes the gases to rise. This is known as **plume rise** and also allows the air pollutants emitted in this gas stream to be lofted higher in the atmosphere. As the plume is going higher in the atmosphere and at certain distance from the ground, the plume will disperse more before it reaches ground level.

The actual height of the plume, is referred as the **effective stack height** (H), it is the sum of the physical height of stack (hs) and the plume rise (Δh). Plume rise is basically calculated as the distance to the imaginary centreline of plume rather than to the lower or upper edge of the plume (Figure 2-1). Plume rise actually depends upon the stack's physical characteristics and also on the effluent's (stack gas) characteristics. The difference in the temperatures between the exhaust gases (Ts) and ambient air (Ta) determines the plume density which affects the plume rise. Also, the velocity of the stack gases is a function of the stack diameter and the volumetric flow rate of the gases determines the plume's momentum.

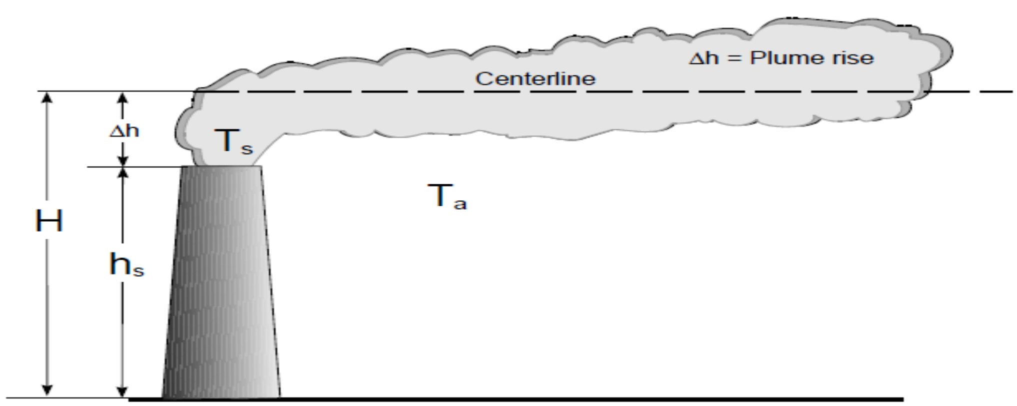


Figure 2-1 Plume rise

2.4 MOMENTUM BUOYANCY

The atmosphere conditions, including the winds and temperature profile, will largely determine the plume's rise along the path of the plume. Two plume characteristics which influences the plume rise: momentum and buoyancy. The velocity of the exhaust gases leaving from the stack generally contributes to the rise of the plume in the surrounding. This momentum carries the effluent gases out of the stack to the point where the atmospheric conditions begin to affect the plume. Once emitted, the initial velocity of the plume is quickly reduced by entrainment as the plume acquires horizontal momentum from the wind. This causes the plume to bend over. The greater the wind speed is, the more horizontal momentum the plume acquires. Wind speed usually increases with distance above the earth's surface. As the plume continues upward the stronger winds tilt the plume even further. This process continues until the plume may appear to be horizontal to the ground. The point where the plume looks level may be a considerable distance downwind from the stack. The speed of wind is important in blowing the plume over. As the wind is stronger, the faster the plume will tilt over.

Plume rise is due to the buoyancy is a function of the temperature difference between the surrounding atmosphere and the plume. The atmosphere when it is unstable, as the plume rises the buoyancy of the plume increases, finally increasing the plume height. In an atmosphere which is stable, as the plume rises buoyancy of the plume decreases. Finally, in the neutral atmosphere, the buoyancy of the plume remains unchanged.

The Buoyancy is taken out from the plume by the same mechanism that tilts the plume towards the wind. As shown in Figure 2-2, due to the mixing of the plume it pulls the atmospheric air into the plume. As the wind speed is very high, the faster is the mixing with outside air takes place. The ambient air is entrained into the plume by the wind "robs" the plume due to its buoyancy, so that on the windy days the plume does not goes very high above the stack.

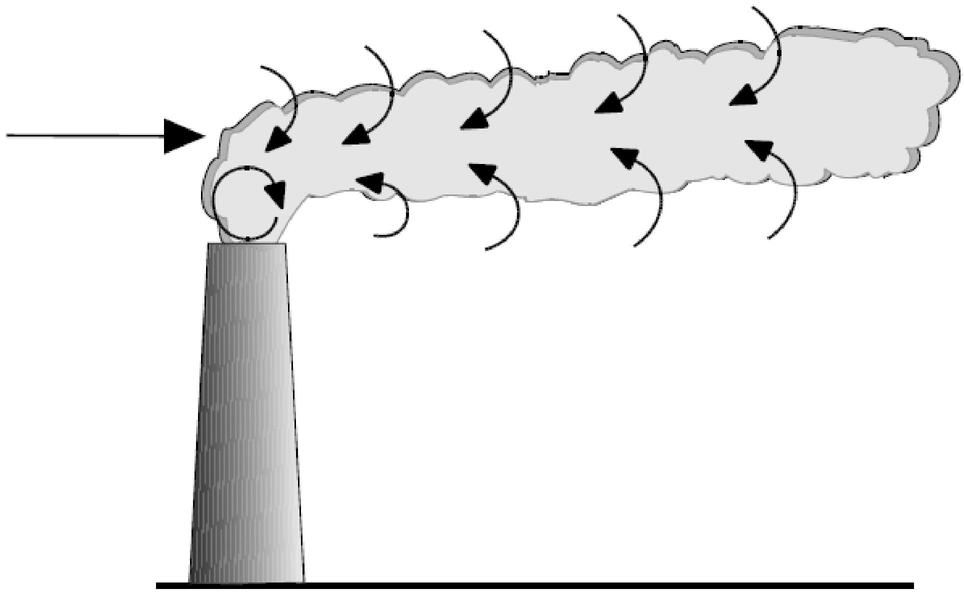


Figure 2-2 Wind affecting entrainment

2.5 EFFECTS OF SOURCE ON PLUME RISE

Due to the physical structure of the stack or the adjacent buildings, this plume may not rise up freely into the atmosphere. Due to Some aerodynamic effects the wind moves around the stack and the adjacent buildings which can force the plume towards the ground and instead of allowing it to go up in the atmosphere.

Stack tip downwash occurs when the ratio of the stack gases exit velocity to wind speed is small. In this case, low pressure wake is formed behind the stack which may cause the plume to be drawn towards downward behind the stack. Dispersion of pollutant is reduced when this mechanism occurs and thus lead to elevated pollutant concentrations immediately to the downwind of the source.

As the air moves over and around the buildings and other structures, turbulent wakes are generated. The plume can be pulled down into this low pressure wake area which depends, upon the release height of a plume (stack height). This is known as aerodynamic or building downwash of the plume and which can lead to elevated pollutant concentrations immediately downwind of the source.

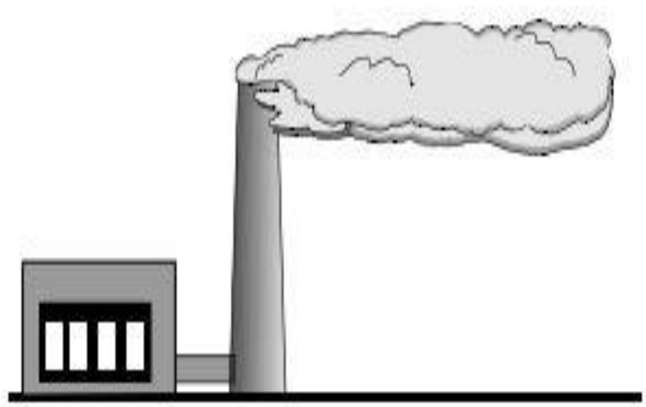


Figure 2-3 Stack dip downwash

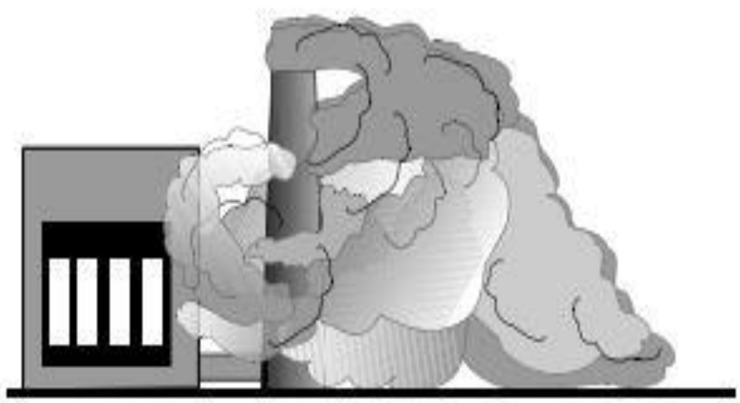


Figure 2-4 Building downwash

2.6 CORRELATIONS FOR PLUME RISE

The most common plume rise formulas are those developed by Gary A. Briggs. One of these that applies to buoyancy-dominated plumes is included in Equation 6-1. Plume rise formulas are to be used on plumes with temperatures greater than the ambient air temperature. The Briggs' plume rise formula is as follows:

$$\Delta h = \frac{1.6\, F^{1/3} x^{2/3}}{\bar{u}} \tag{2.1}$$

$$\text{Buoyancy flux} = F = \frac{g}{\pi} V \left(\frac{T_s - T_a}{T_s} \right) \quad (2.2)$$

Plume rise formulas calculate the imaginary centreline for the plume. The centreline is the line where the highest concentrations of pollutants occur. Several methods are used to determine pollutant concentrations away from the centreline.

2.7 STABILITY CLASSIFICATIONS

As examined already, the stability of the environment relies upon the temperature difference between an air package and the air surrounding it. Therefore, the different levels of stability can based on how much the large or small the temperature difference is between the air parcel and the surrounding air. The atmosphere can be put under some conditions which are stable, conditionally stable, neutral, conditionally unstable, or unstable. However, for dispersion calculation and modelling purposes, these levels of stability are generally classified into six stability classes which are based upon five surface wind speed categories, three types of daytime insolation, and two types of night time cloudiness.

2.8 GAUSSIAN DISTRIBUTION

The Gaussian model which uses the Gaussian distribution equation to simply calculate the variations of pollutant concentrations away from the centre of the plume. This equation calculates the ground level pollutant concentrations depend upon time-averaged atmospheric variables (e.g. wind speed and temperature,). Thus, an instantaneous "picture" of the plume's concentrations cannot be determined. However, when the time averages of ten minutes to one hour is used to calculate the time-averaged atmospheric parameters needed in the Gaussian distribution equation, thus the pollutant concentrations in the plume can be easily assumed to be normally distributed.

Gaussian distribution equation:-

$$\chi = \frac{Q}{2\pi\sigma_y\sigma_z u} e^{\frac{-1}{2}\left(\frac{y}{\sigma_y}\right)^2} \left\{ e^{\frac{-1}{2}\left(\frac{z-H}{\sigma_z}\right)^2} + e^{\frac{-1}{2}\left(\frac{z+H}{\sigma_z}\right)^2} \right\} \quad (2.3)$$

2.9 APPLICATION OF CFD:-

- CFD is used in simulating the flow around the vehicles. For example, it is applied in study of the interaction of propellers and rotors with the aircraft fuselage.
- CFD is used to study the circulatory and respiratory systems in Bio-medical engineering.
- CFD is more used in industry as it is more cost-effective tthan any physical testing. However, one should note that complex flow simulations are challenging and it takes a lot of engineering experienced to obtain validated solutions.
- In Electrical and as well as in electronics engineering it is used in cooling of equipment including microcircuits.
- In process engineering for chemical engineer, mixing and separation simulations are done in CFD.

CHAPTER 3

METEOROLOGICAL DATA

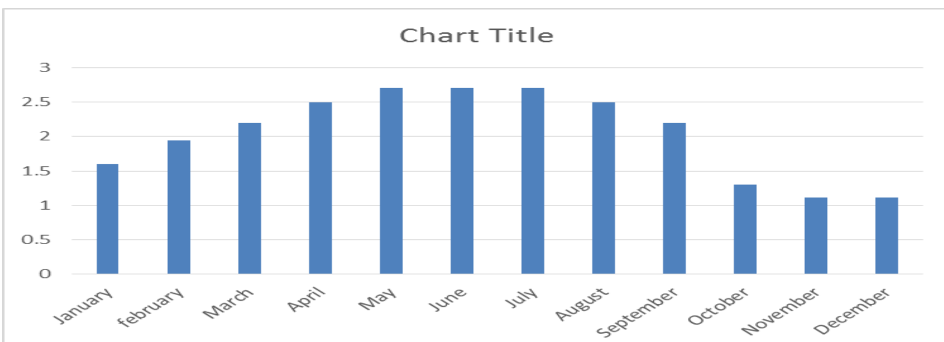
3.1 EFFECT OF METEROLOGICAL CONDITIONS ON PLUME DISPERSION

Parameters that directly influence the dispersion of pollutants include, wind speeds and direction, atmosphere stability and mixing layer depths. Meteorological conditions that may lead to high ground level concentrations (HGC) from elevated point sources are typically either convective atmospheric stability with light winds or neutral conditions with high wind speeds. Both of these conditions lead to the plume rapidly being carried to ground level close to source. High concentrations from low elevated sources, elevated sources with building or topography effects, or virtual sources are typically due to stable conditions with light winds.

The local meteorology of the region must be characterized to evaluate the short term atmospheric dispersion and transport of emissions released by facility. The data required predicting dispersion and transport includes: wind speeds and direction, temperature, atmospheric stability and mixing layer depth.

Meteorological data is required for the dispersion modelling as it gives the data for the wind velocity, temperature.

Table 3-1 Average wind speed



The average wind speed for the Rourkela is given in this graph which is around 2m/s. For the best engineering design the plume dispersion should be done for the best and the worst conditions. Fort this worst condition wind speed can go to more than 11m/s. So the stack must be design in such a way that in these worst condition it can throw the pollutants away from the city or the biotic environment should not be effected.

CHAPTER 4
MODELLING AND SIMULATION

4.1 THE PROBLEM STATEMENT

The present project work consists of 3D rectangular area having horizontal distance of 1000m, vertical distance of 300m and width of 100m. Inside the rectangular area stack is present of height 50m and diameter 5m which through the pollutants to atmosphere. Wind is flowing in positive X-direction and considering the different velocities of wind as 1m/s, 2m/s, 5m/s, and 10m/s. Different velocities of gases from stack are taken as 5m/s, 8m/s, and 10m/s. Mass fractions of the pollutants (SO_2, NO_2, CO, PPM_{10}) coming out from stack are known. Mass diffusivities of different pollutants with respect to air are also known. On each value of wind velocity by varying the stack velocity, different types of plume dispersion is observed. The geometry of the problem is created using Workbench, followed by meshing. The rest of work which includes providing initial and boundary conditions etc. is done in Fluent. Thus the concentration of pollutants at different heights and horizontal distance is calculated using ANSYS. Tabulation and plotting is done to get an idea about the relation among the pollutants concentration and distance.

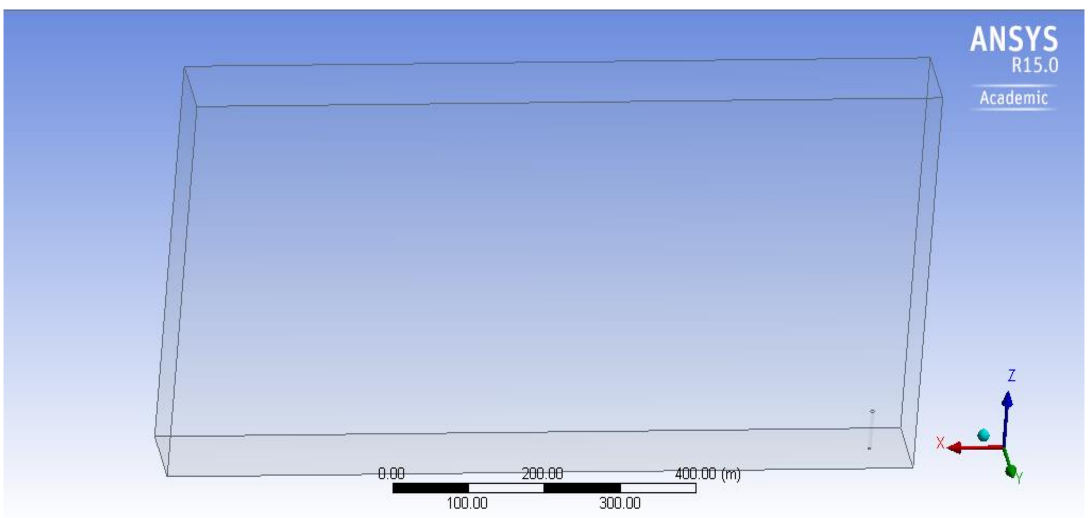


Figure 4-1 Geometry

Input Data for Dispersion Modelling

Stack height- 50m

Stack diameter- 5m

Exit velocity- 5m/s, 8m/s, 10m/s

Temperature- 400K

Emissions of Pollutants (Mass fractions)

SO_2- 0.866

NO_2- 0.10

CO- 0.03

PPM_{10}- 0.004

4.2 MESH

Meshing is basic requirement for the simulation process. To analyse the fluid flow problems, the flow domains are divided into the smaller subdomains. For the meshing, fine tetrahedron mesh is done in 3d geometry. After that named selection was done which was named as inlet, inlet1, symmetry, wall for the entire geometry.

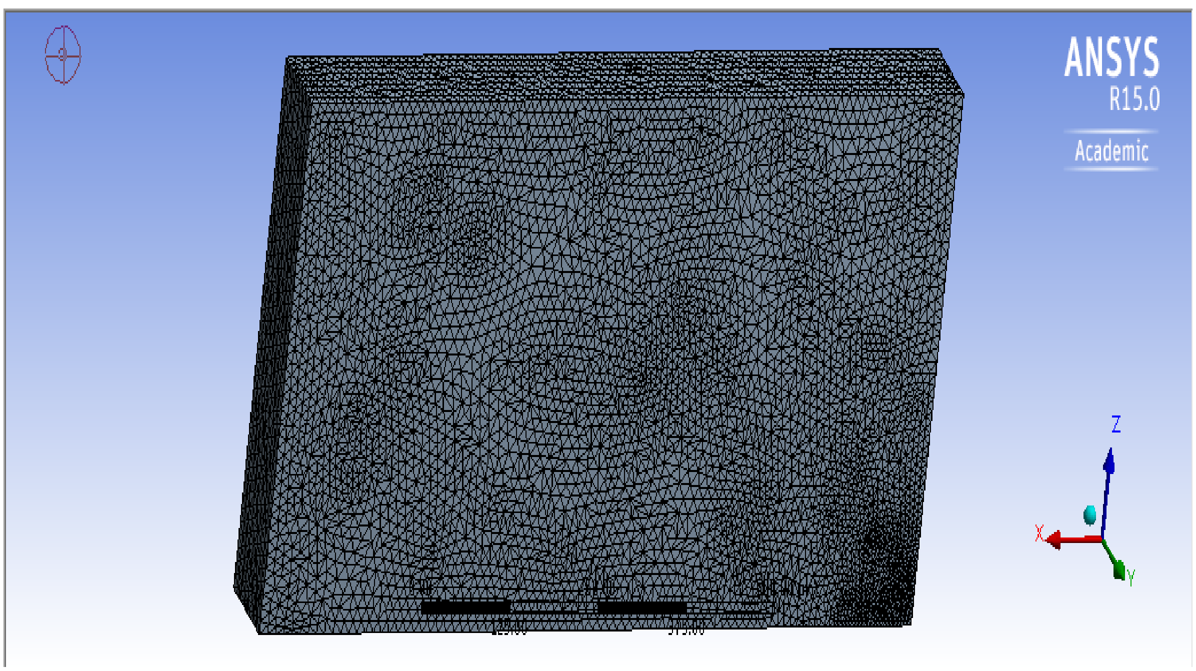


Figure 4-2 Meshing of geomerty

4.3 MODELLING EQUATIONS

4.3.1 Continuity equation

Equation for mass conservation equation or also known as continuity equation is written as:-

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \overline{v}) = S_m$$

(4.1)

4.3.2 Transport equation for multiphases flow

For the species transport in ANSYS FLUENT it solves the transport equation inside the domain which is given as :-

$$\frac{\partial \alpha_l \rho_l \phi_l^k}{\partial t} + \nabla \cdot \left(\alpha_l \rho_l \overline{u}_l \phi_l^k - \alpha_l \Gamma_l^k \nabla \phi_l^k \right) = S_l^k \quad k = 1, \ldots, N$$

(4.2)

4.4 SOLUTION METHODOLOGY

For the simulation process Phase coupled SIMPLE was chosen for the pressure-velocity coupling. Second order Upwind scheme was chosen for the discretization of partial differential equation. In the final step of simulation iterations were given which were as follows:-

Step size – 0.05

Number of steps – 10000

CHAPTER 5

RESULTS AND DISCUSSION

5.1 For wind velocity 1 m/s

The concentration of SO_2, NO_2, CO, and PPm are plotted at against the horizontal distance which is upto 1000m and at different heights (z = 0m GLC , and at z = 10m)

a)-For stack velocity 5m/s and at z = 0m

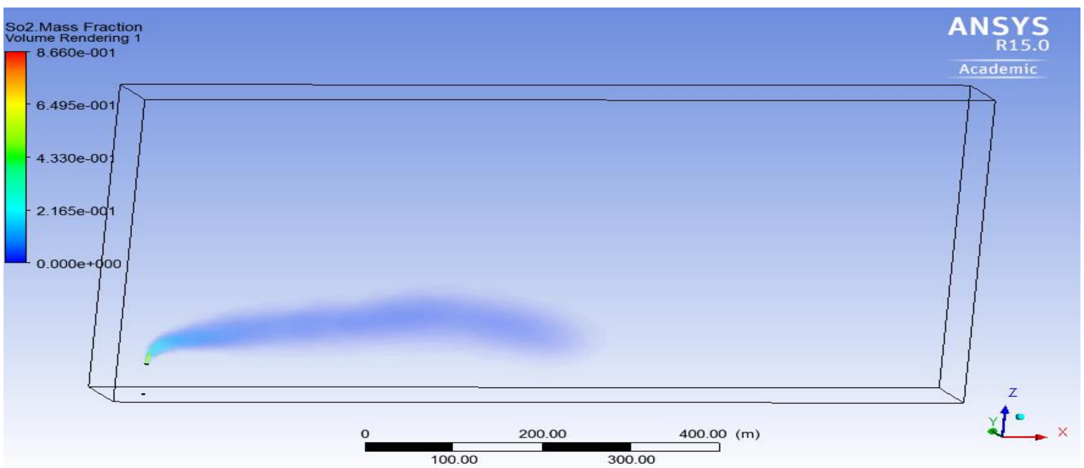
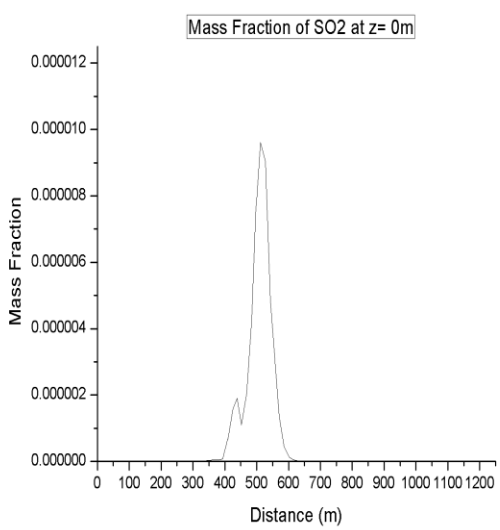
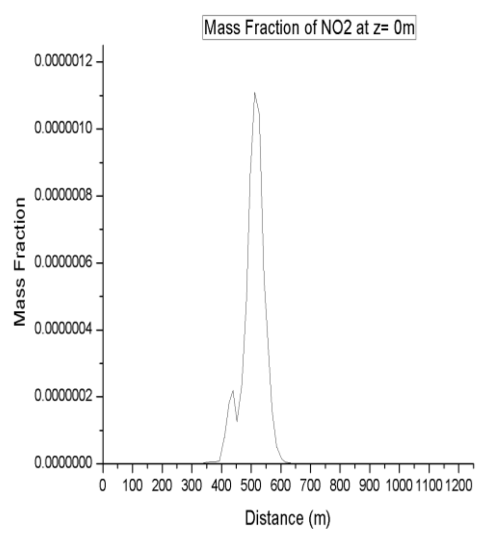


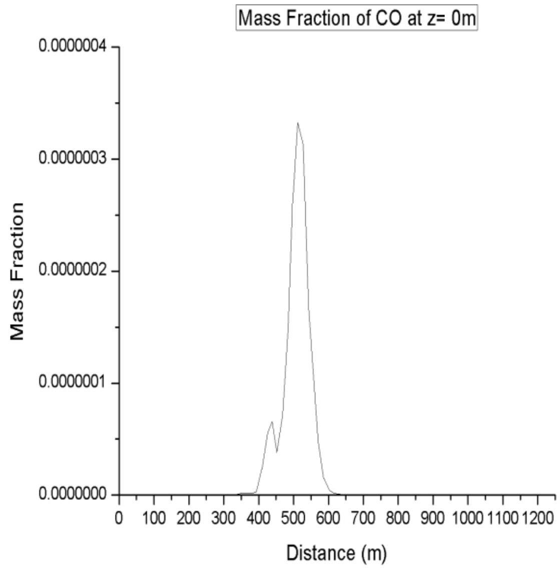
Figure 5-1 plume dispersion for wind velocity 1m/s and stack velocity 5m/s

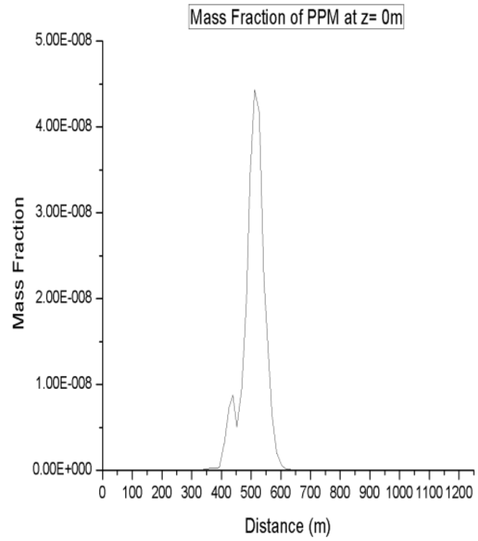


(a)



(b)



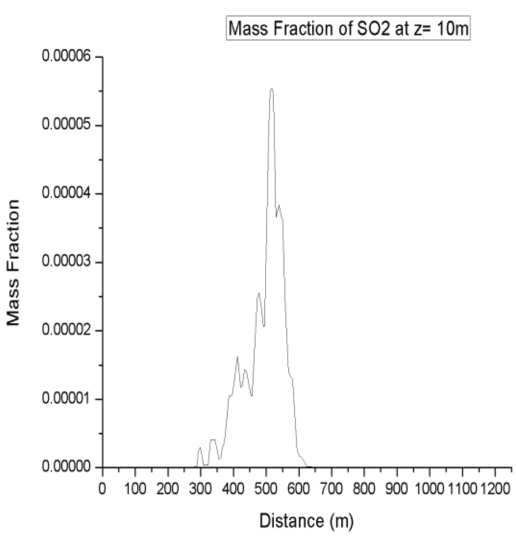


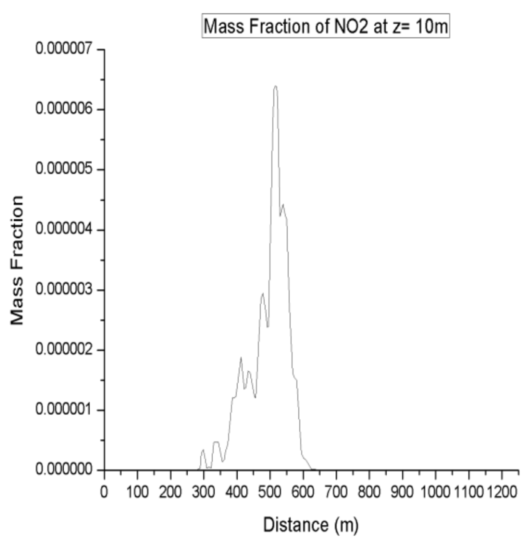
(c) (d)

Figure 5-2 Mass fraction plots for (a) So2, (b) No2, (c) CO (d) PPM

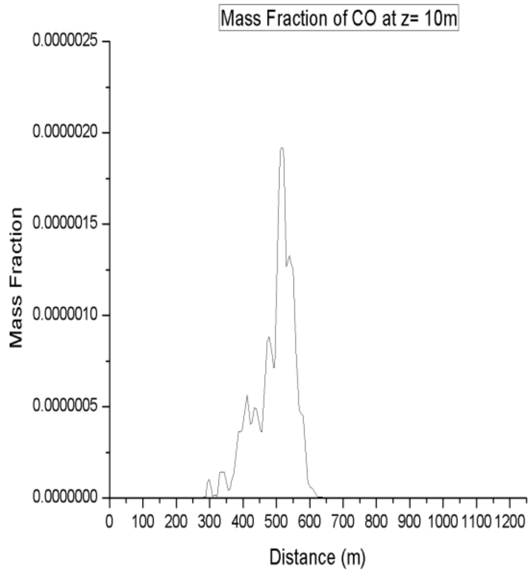
In the Figure 5.2, When the wind is 1m/s the ground level concentration is extremely at and at 500m from the stack the stack the concentration of SO_2 is 0.000010 , for NO_2 is 0.0000010 , for CO is 0.00000033 and for ppm is 5.00E-008. These concentrations are in under the limiting values given by the EPA.

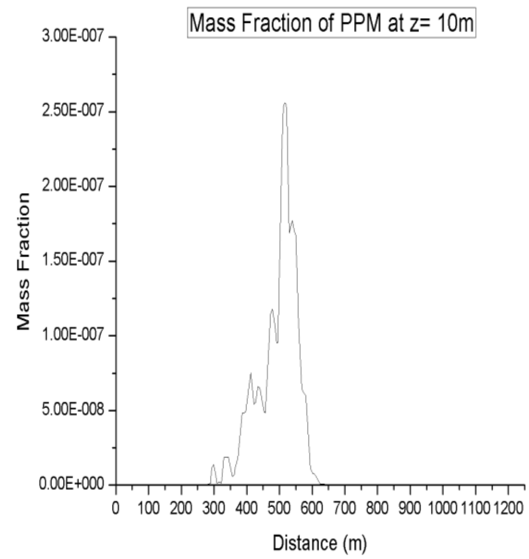
b) For stack velocity 5m/s and at z = 10m





(a) (b)



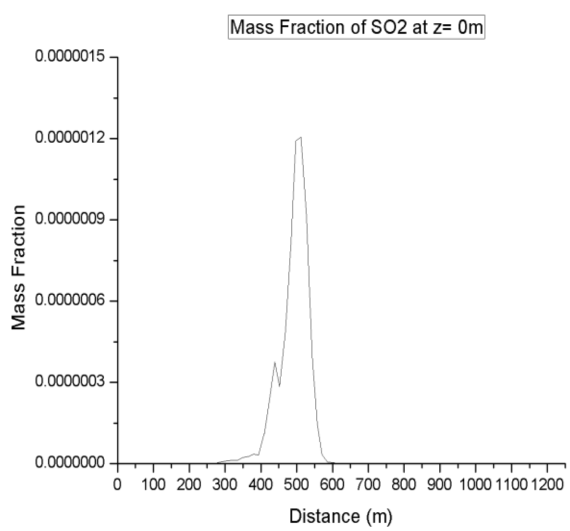


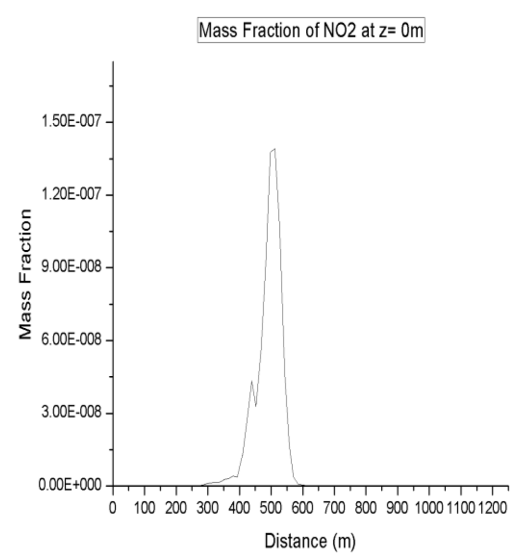
(c) (d)

Figure 5-3 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

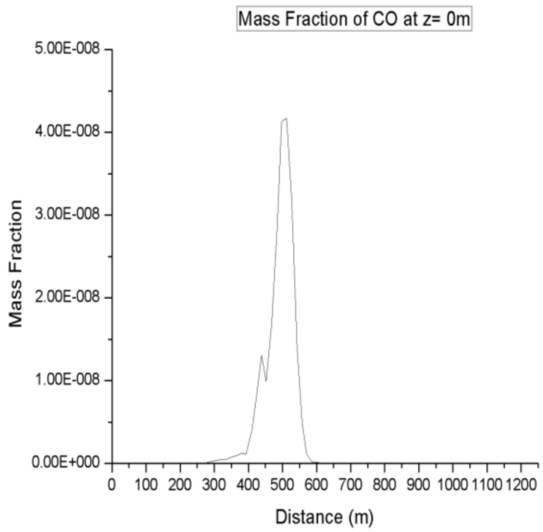
In the Figure 5-3, As the height increases the concentration of pollutant increases as shown in plotting.

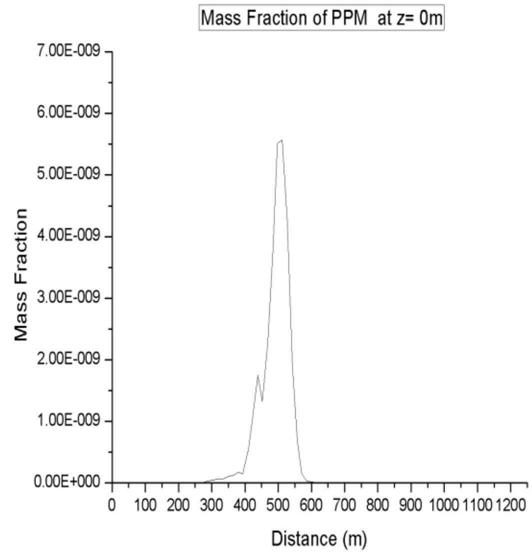
c) Stack velocity 8 m/s at Z= 0m





(a) (b)





(c) (d)

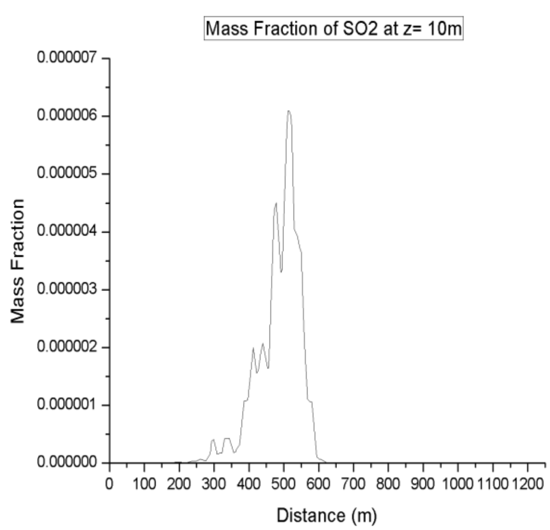
Figure 5-4 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

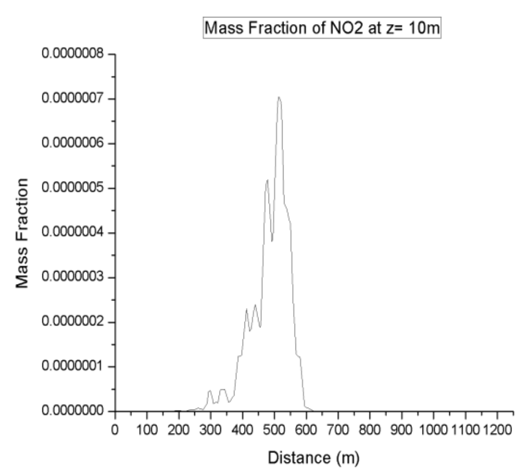
In the Figure 5-4, As the stack velocity is increased to the 8m/s the concentration of pollutants are in decreasing as compared to the stack velocity 5 m/s.

SO_2 – 0.0000012 at 500m and after that it is decreased.

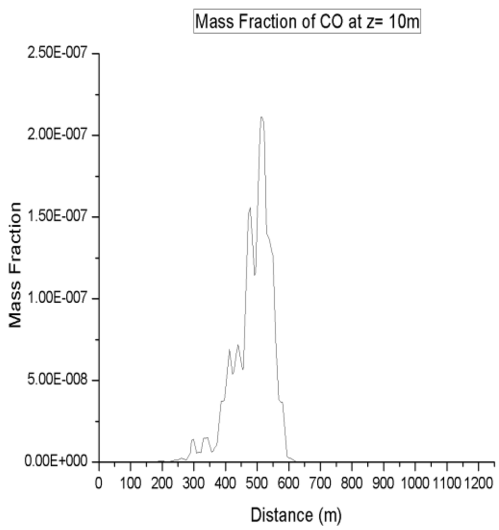
NO_2- 1.30E-007 at around 500m which is very low.

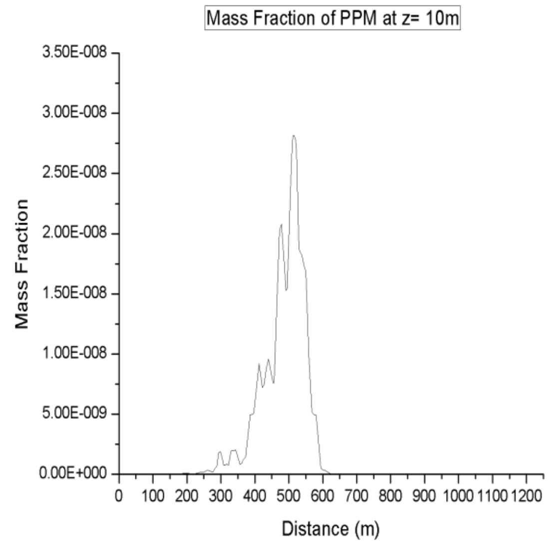
d) Stack velocity 8 m/s at Z= 10m





(a) (b)





(c) (d)

Figure 5-5 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

In the Figure 5-5, Again as the height increases the concentrations of pollutants are increasing as compared to the height at z= 0m but as here stack velocity is 8 m/s more turbulence is there more mass diffusing is occurring which lowers the concentration of pollutants.

e) Stack velocity 10 m/s at Z= 0m.

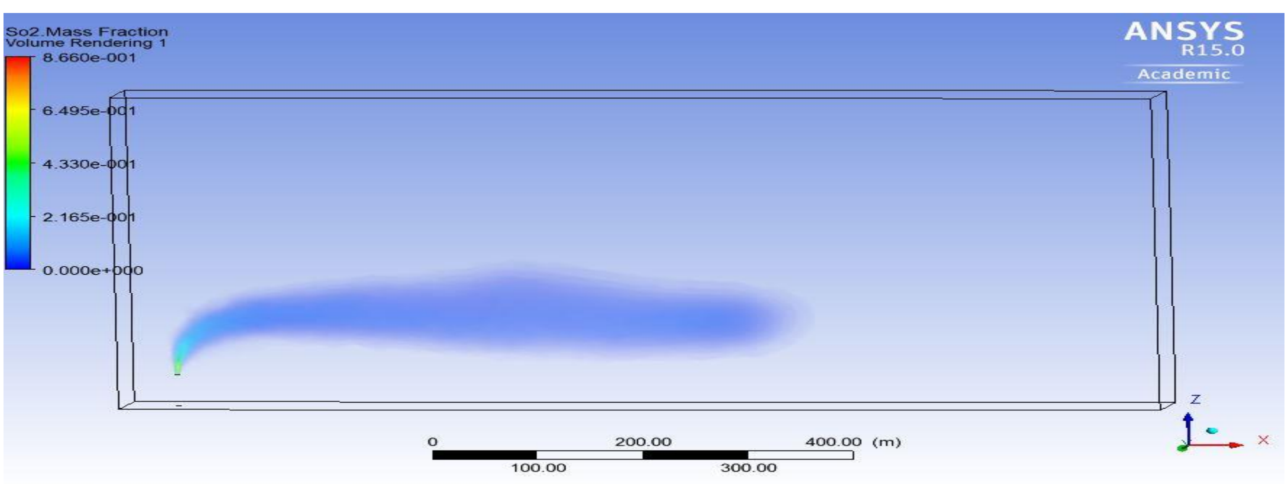
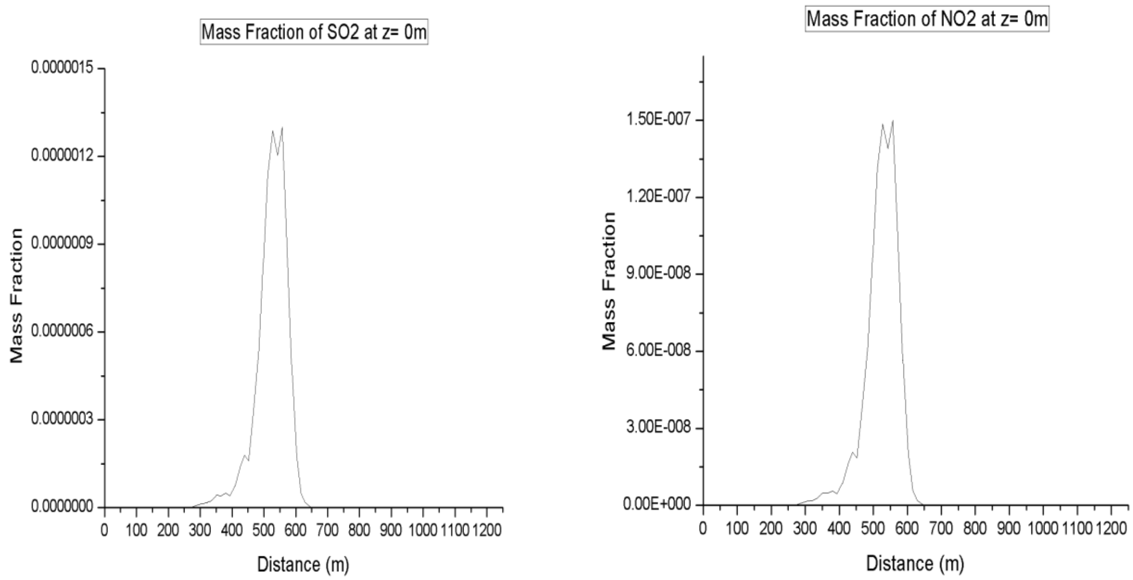
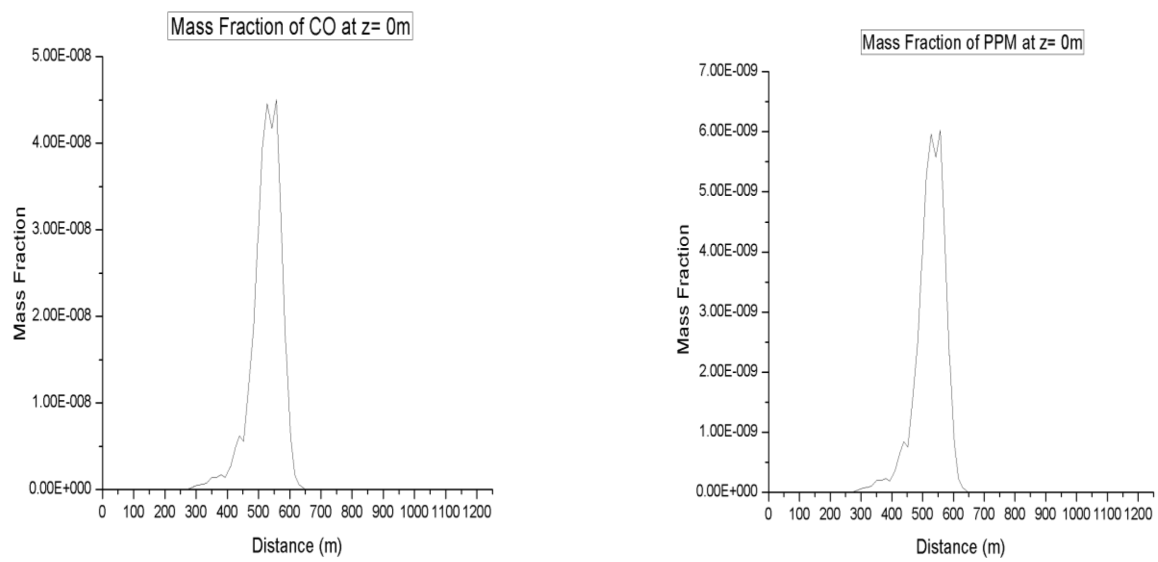


Figure 5-6 Plume dispersion for stack velocity 8m/s



(a) (b)

Figure 5-7 Mass fraction plots for (a) SO_2, (b) NO_2



(c) (d)

Figure 5-8 Mass fraction plots for, (c) CO (d) PPM

In the Figure 5-8, As the stack velocity is increasing the concentration of pollutants is decreasing at Ground Level.

5.2 For wind velocity 2m/s

a) stack velocity 5m/s at z=0m

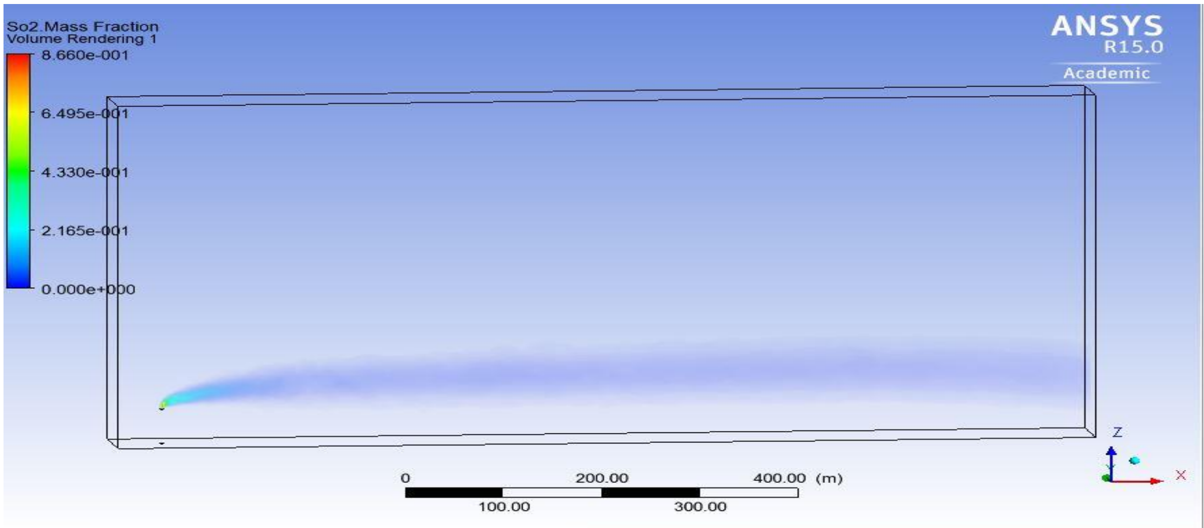
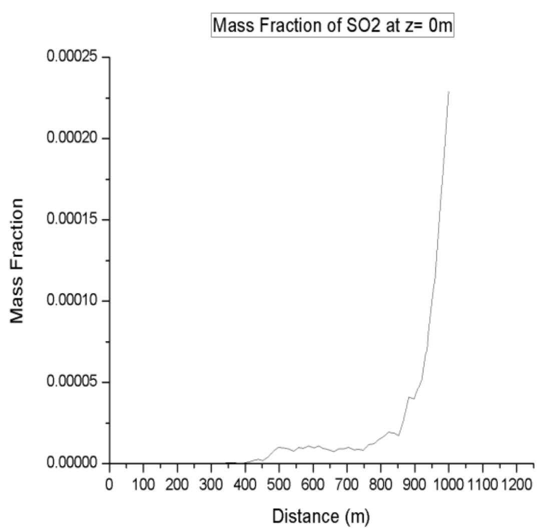
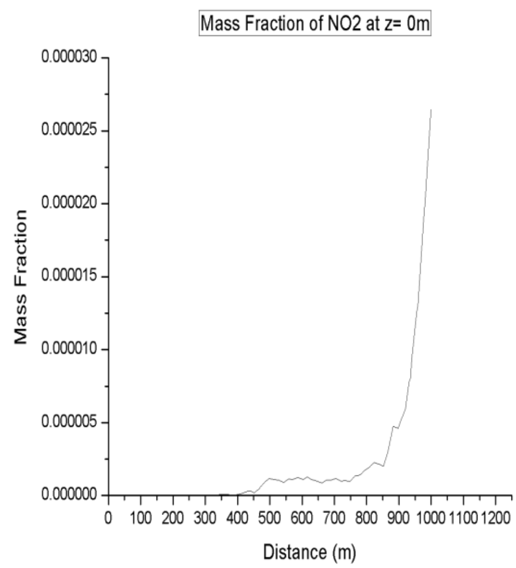


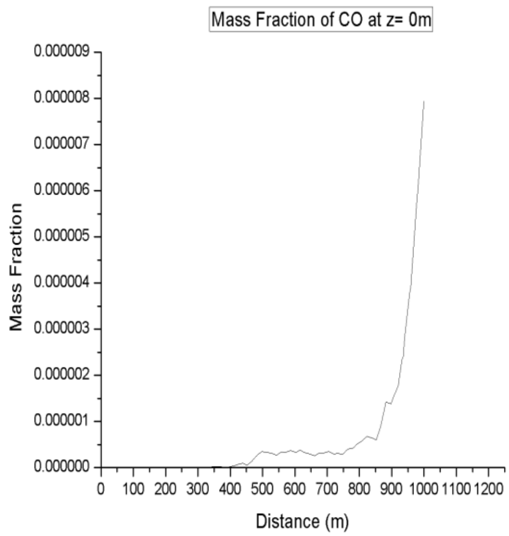
Figure 5-9 Plume dispersion for the stack velocity 5m/s and wind velocity 2m/s



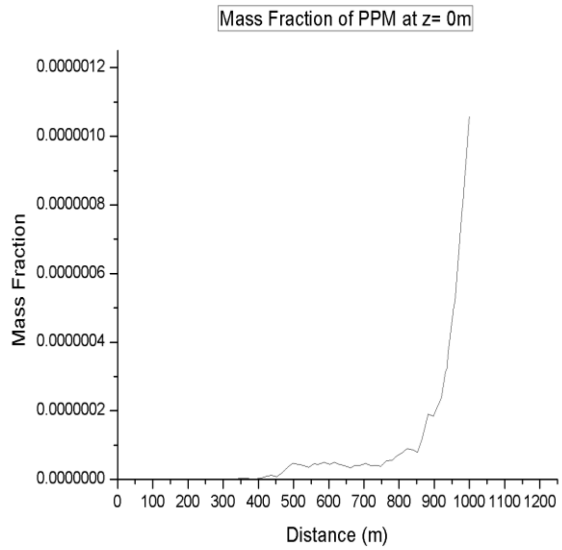
(a)



(b)



(c)



(d)

Figure 5-10 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

In the Figure 5-10, As here the wind velocity is increased to 2m/s the concentration of pollutant is increased in the ground level i.e. SO_2 concentration is 0.00023 at 1000m distance, with respect to wind velocity 1m/s.

b) stack velocity 8m/s at z=0m

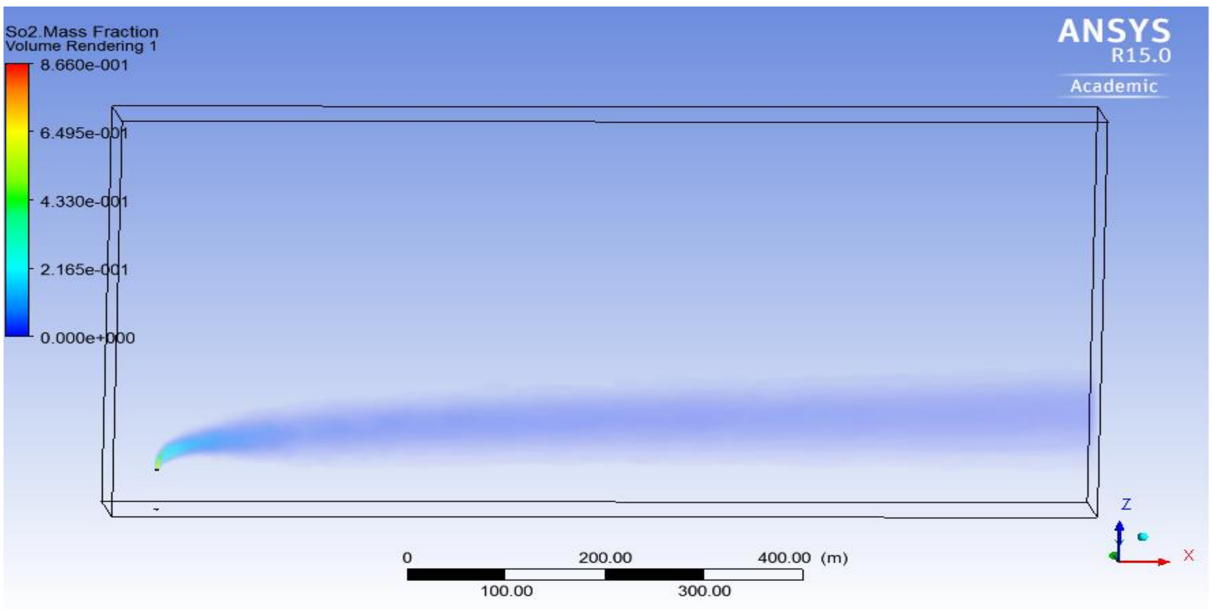
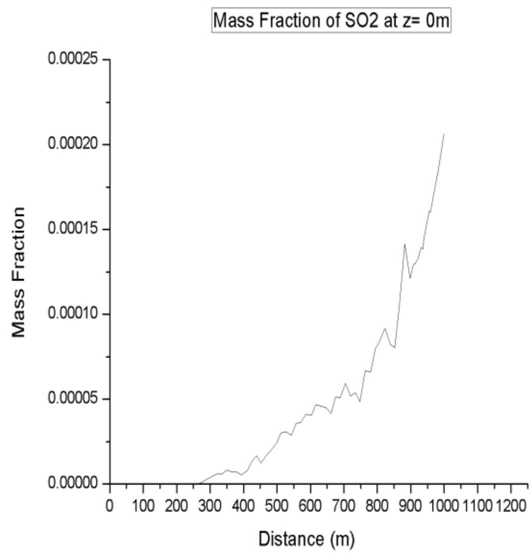
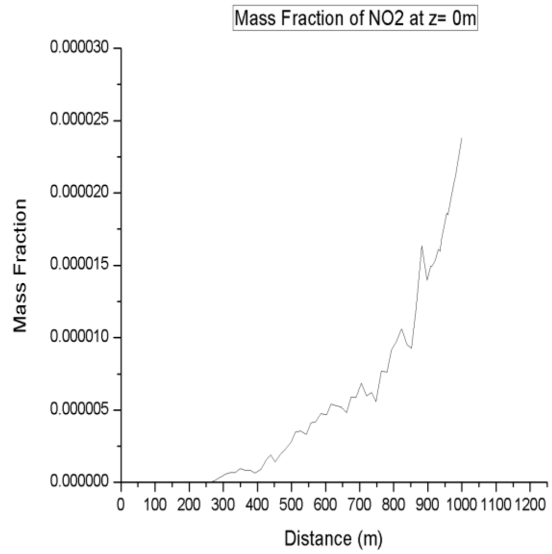


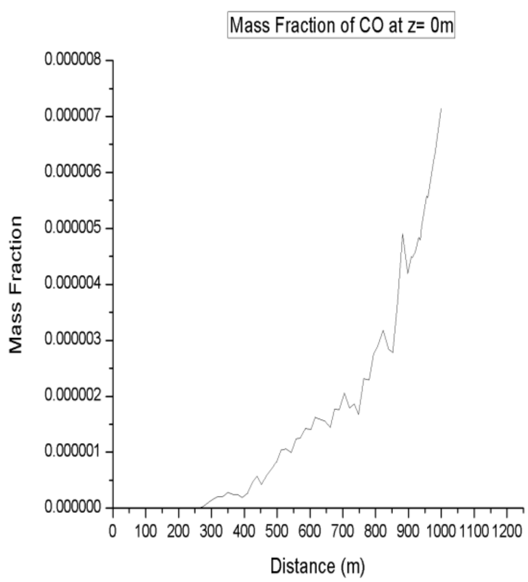
Figure 5-11 Pume dispersion for stack velocity 8m/s and wind velocity 2m/s.



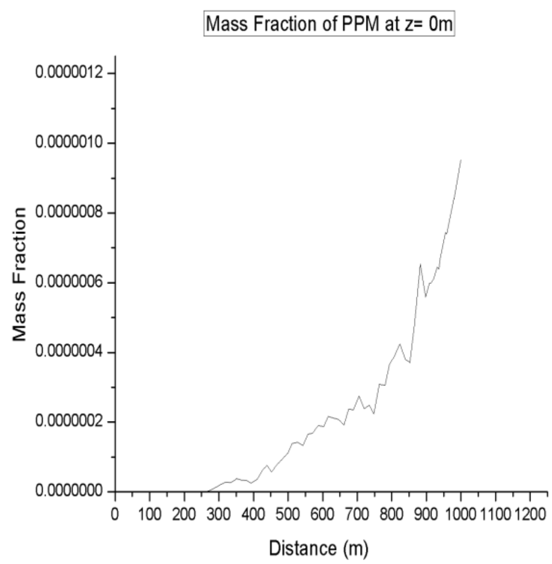
(a)



(b)



(c)



(d)

Figure 5-12 Mass fraction plots for (a) SO_2, (b) NO_2 (c) CO (d) PPM

In the Figure 5-12,In this condition the stack velocity is increased to 8m/s, so here the concentration of pollutants is less than that of stack velocity 5m/s(earlier case).

c) stack velocity 10m/s at z=0m

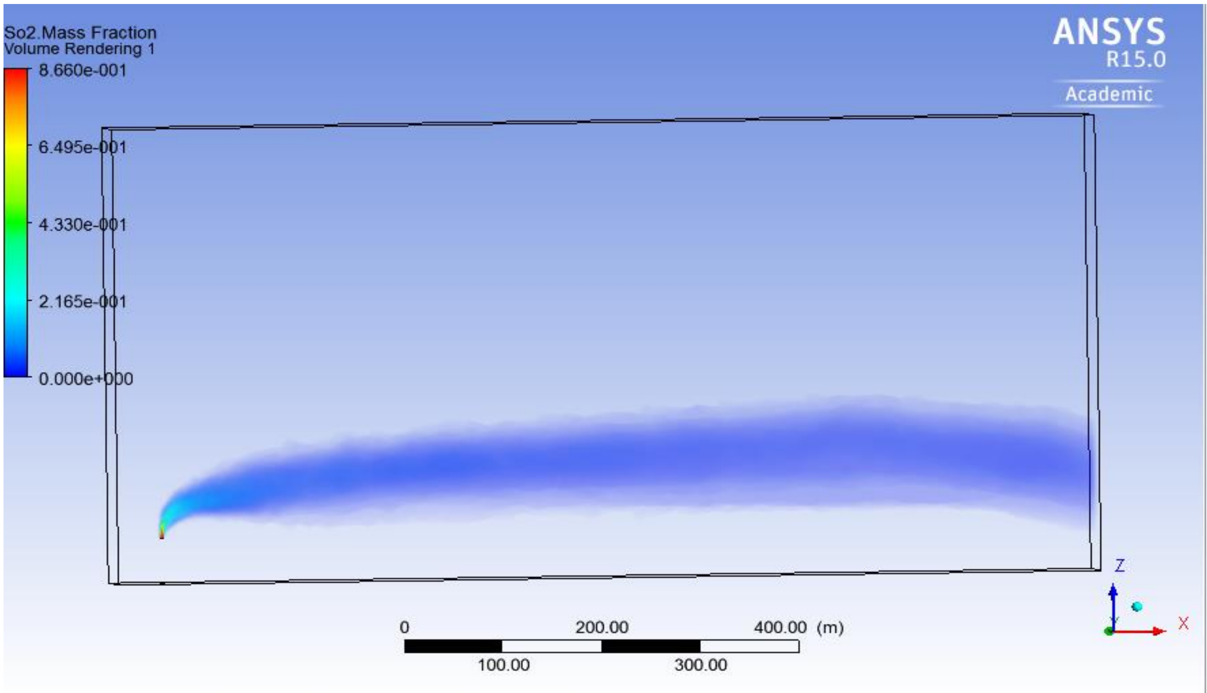
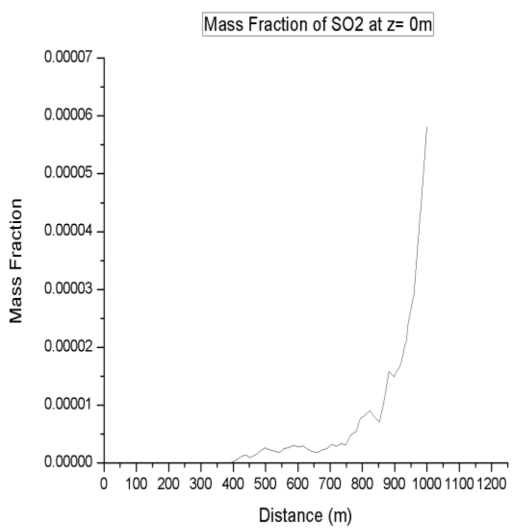
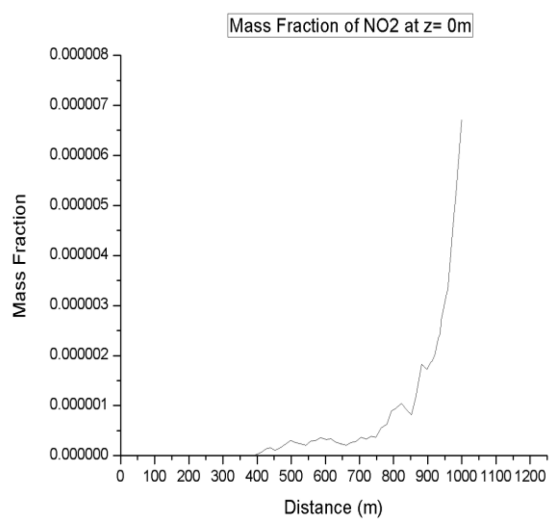


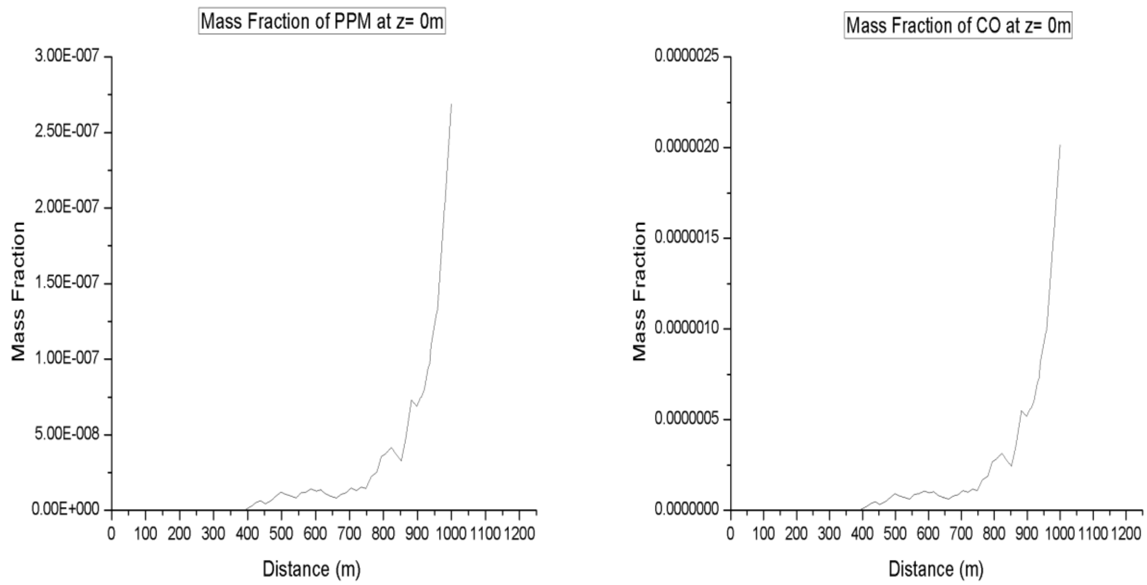
Figure 5-13 Plume dispersion for stack velocity 10m/s and wind velocity 2m/s



(a)



(b)



(c) (d)

Figure 5-14 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

In the Figure 5-14, As the stack velocity is increased to 10m/s the pollutants concentration is decreased in ground level clearly shown in graph. SO_2 concentration 0.00006.

5.3 For wind velocity 5m/s

a) stack velocity 5m/s

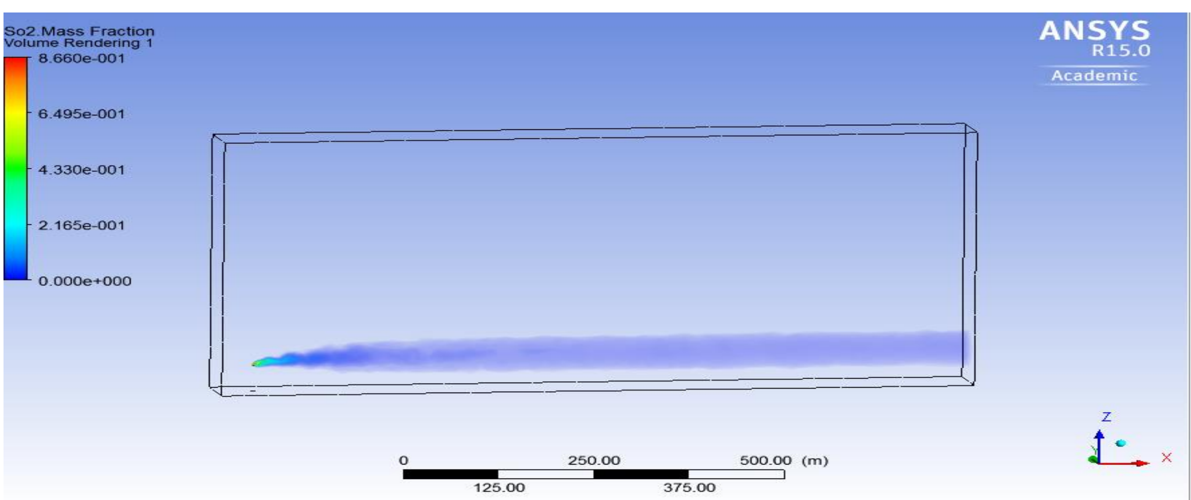
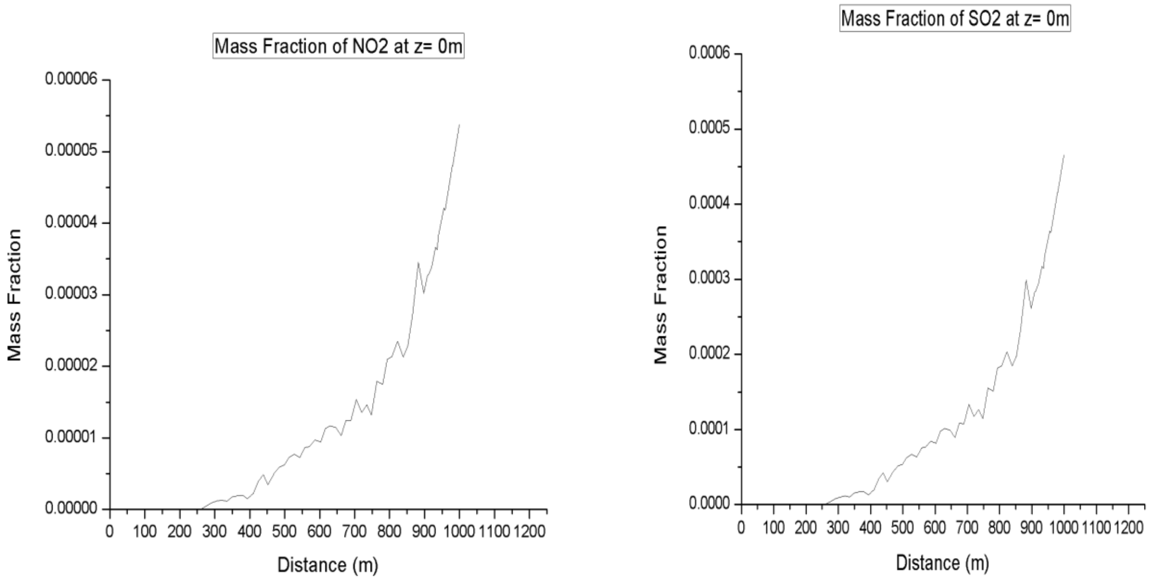
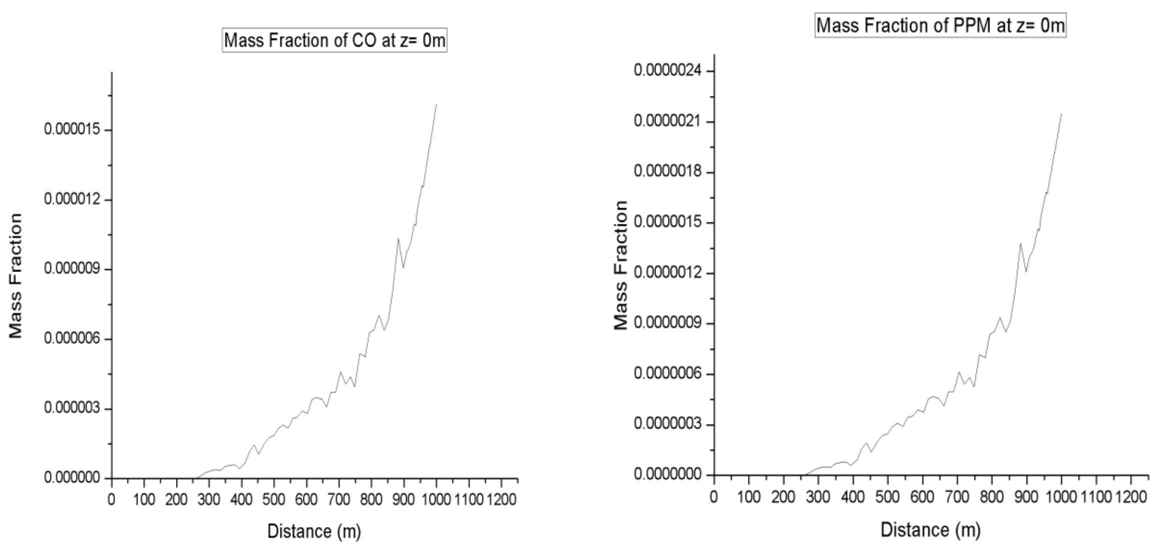


Figure 5-15 Plume dispersion for stack velocity 5m/s and wind velocity 5m/s



(a) (b)

Figure 5-16 Mass fraction plots for (a) NO_2, (b) SO_2

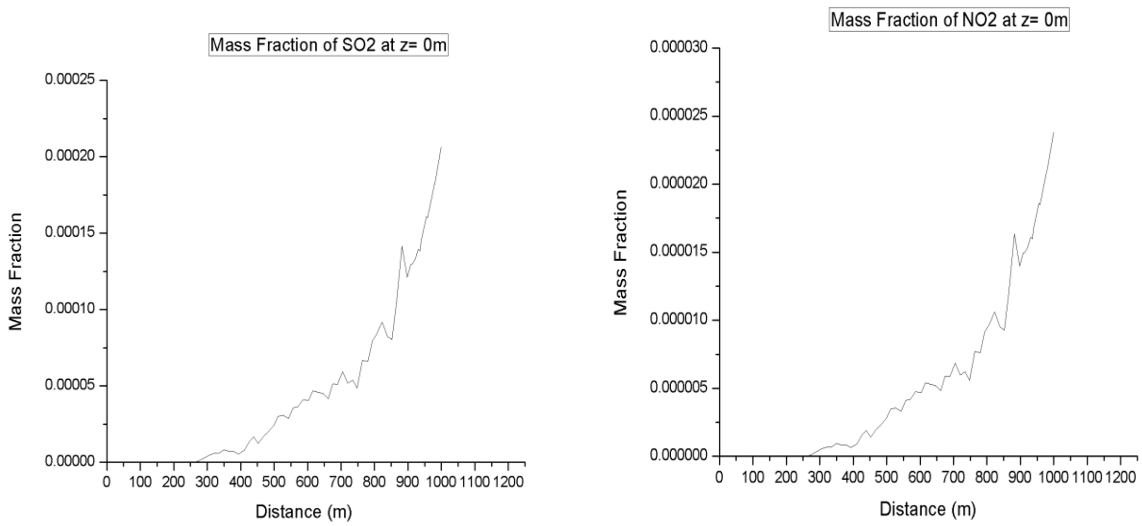


(c) (d)

Figure 5-17 Mass fraction plots for (c) CO (d) PPM

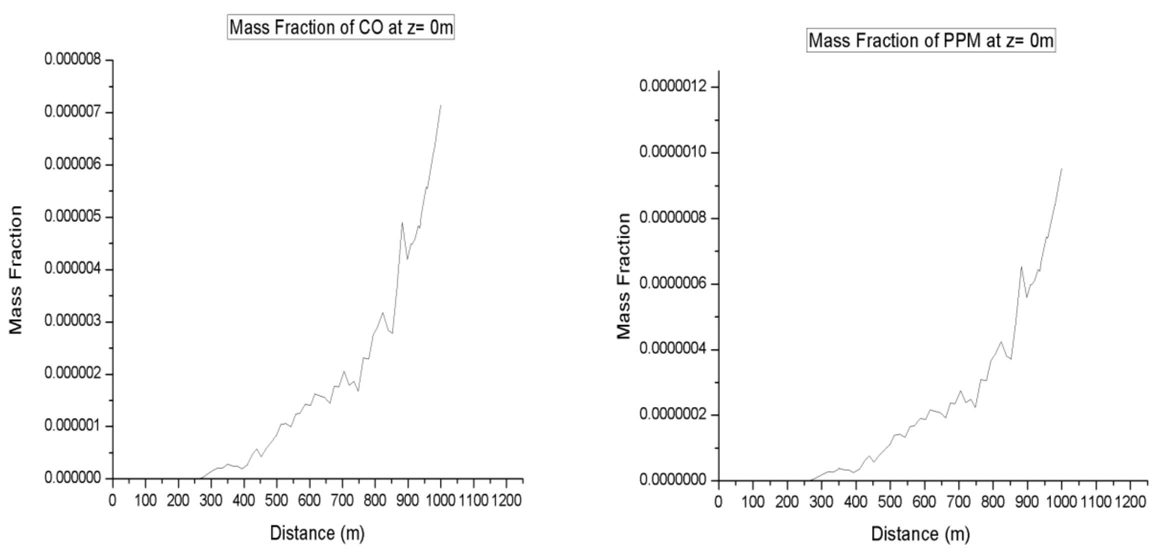
From the Figure 5-17, Here the stack velocity and wind velocity both are equal to 5m/s. That's why in this condition all the pollutant concentration is 0.0004 at 1000m distance in horizontal distance.

b) Stack velocity 8m/s at z=0m



(a) (b)

Figure 5-18 Mass fraction plots for (a) SO_2, (b) NO_2



(c) (d)

Figure 5-19 Mass fraction plots for(c) CO (d) PPM

From the Figure 5-19, As the stack velocity is increased from 5m/s to 8m/s the concentration of pollutants is decreased. Earlier the SO_2 concentration was 0.00043 at 1000m distance here it is decreased to 0.0002.

c) Stack velocity 10m/s at z=0m

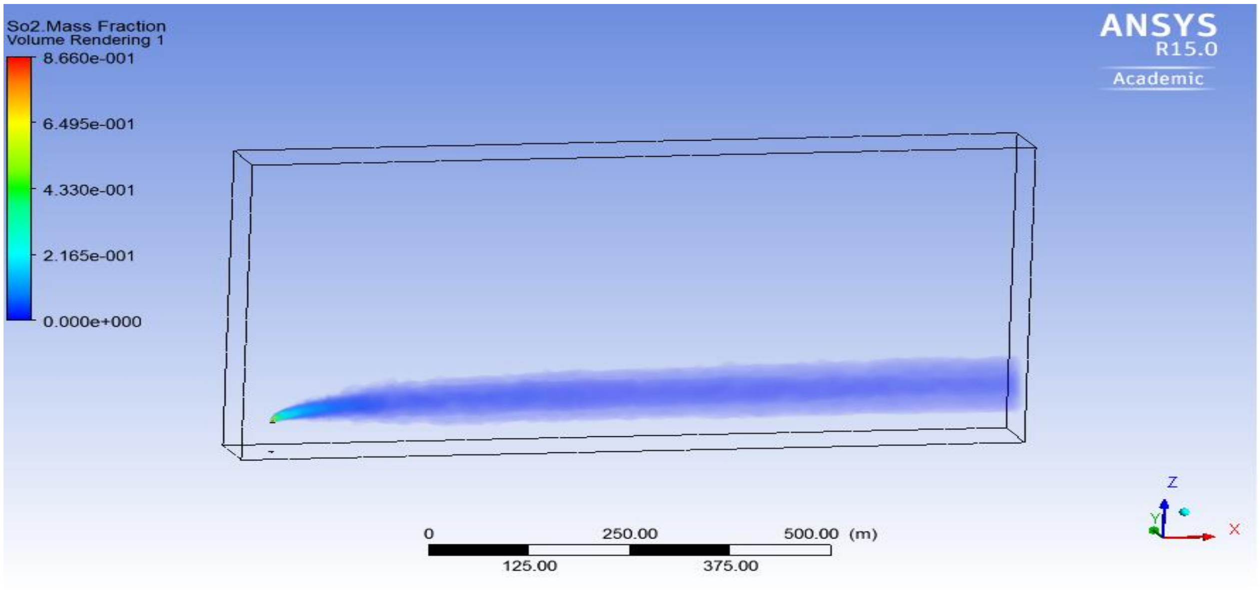
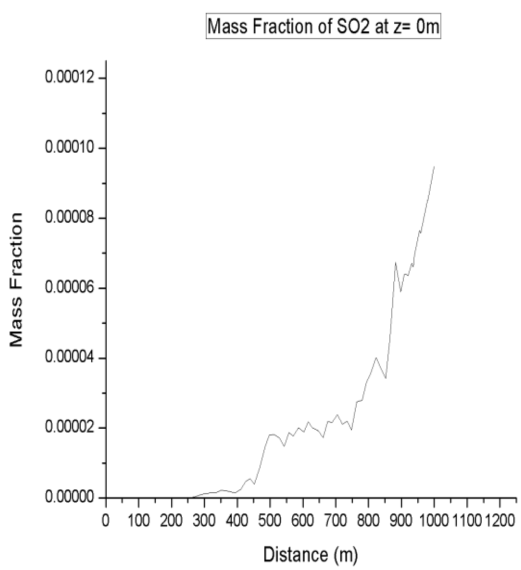
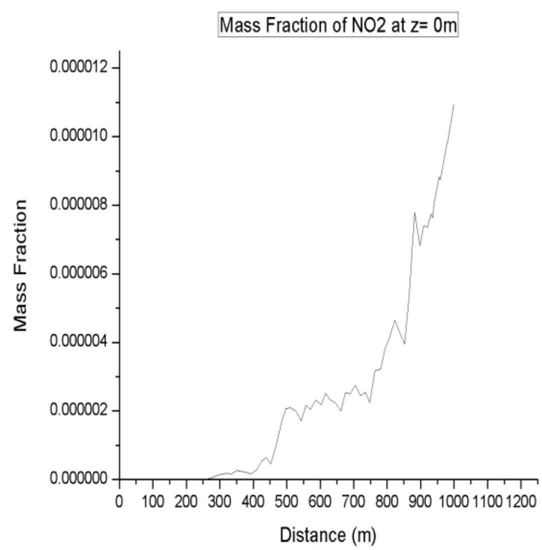


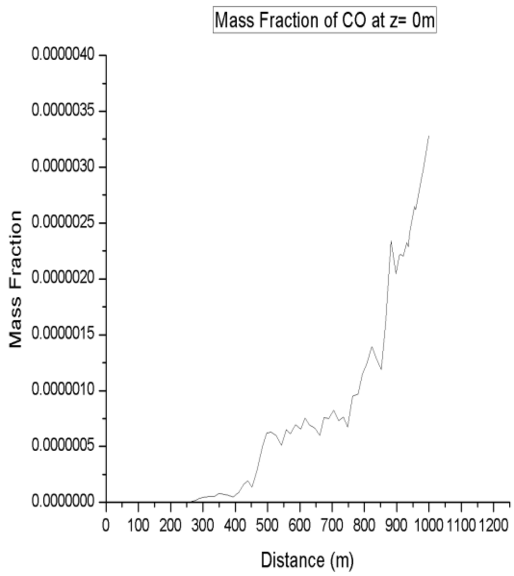
Figure 5-20 Plume dispersion for stack velocity 10m/s and wind velocity 5m/s



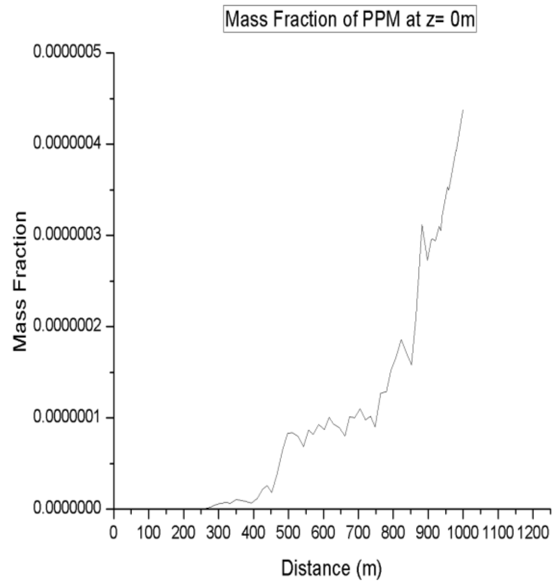
(a)



(b)



(c)



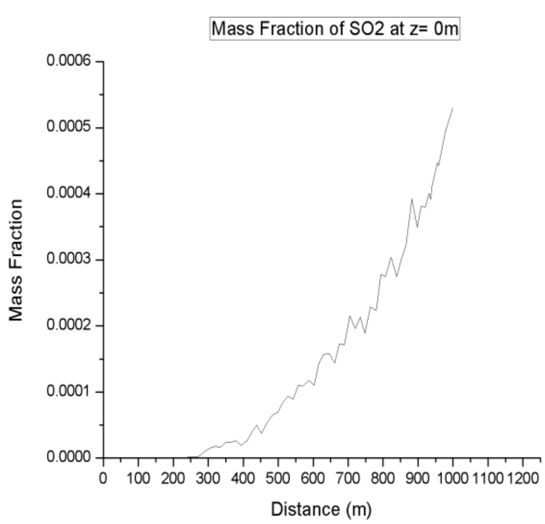
(d)

Figure 5-21 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

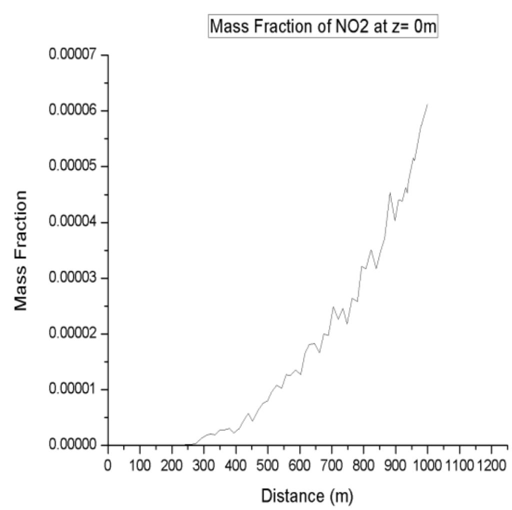
From the Figure 5-21, On increasing the stack velocity to 10m/s the ground level concentration is decreased to 0.0009 with respect to earlier one.

5.4 For wind velocity 10m/s

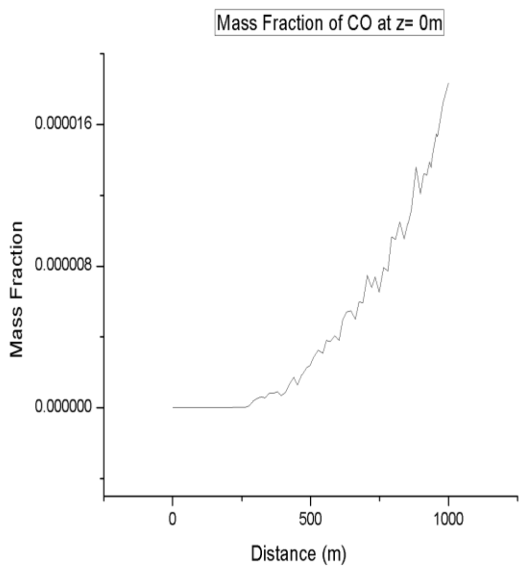
a) Stack velocity 5m/s at z= 0m



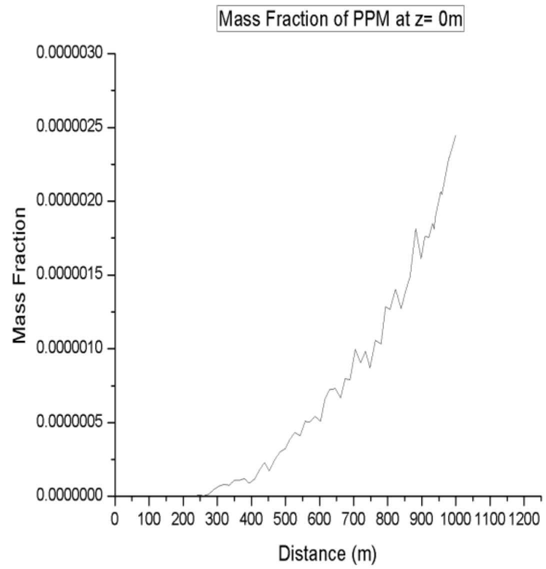
(a)



(b)



(c)



(d)

Figure 5-22 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

From the Figure 5-22 , As the wind velocity is 10m/s and stack velocity 5m/s here concentrations of pollutants is increased. This one is highly not recommended by EPA.

b) Stack velocity 8m/s at z= 0

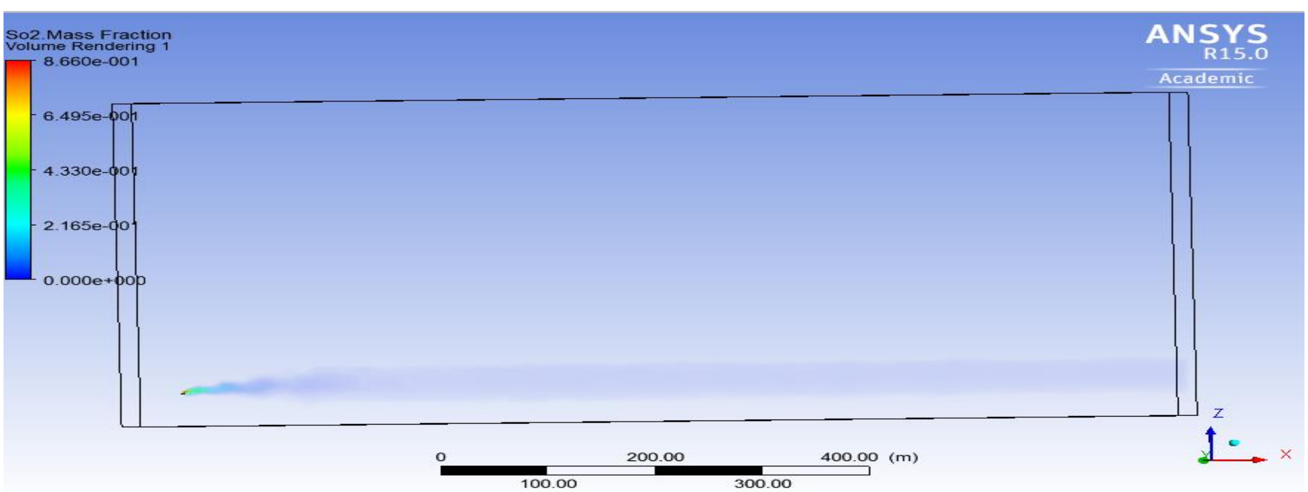
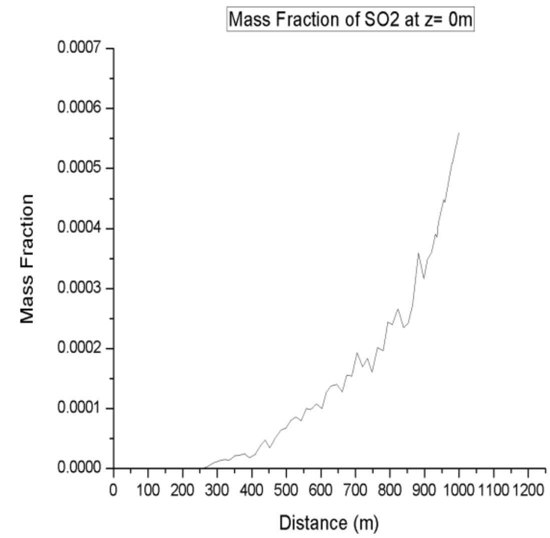
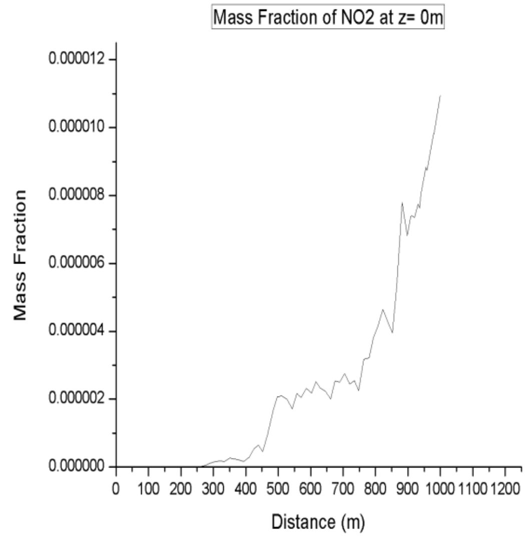


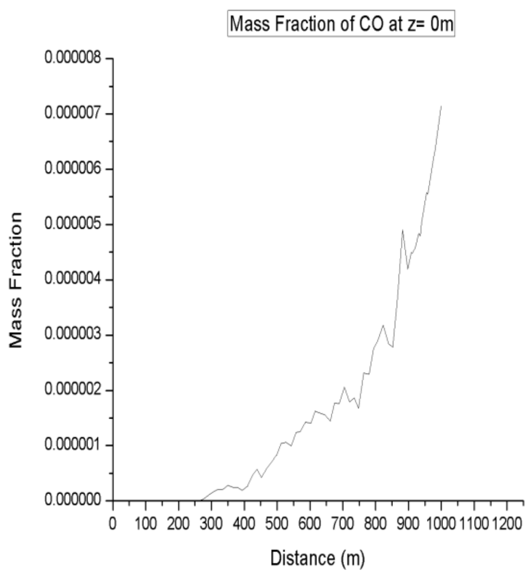
Figure 5-23 Plume dispersion for stack velocity 8m/s and wind velocity 10m/s



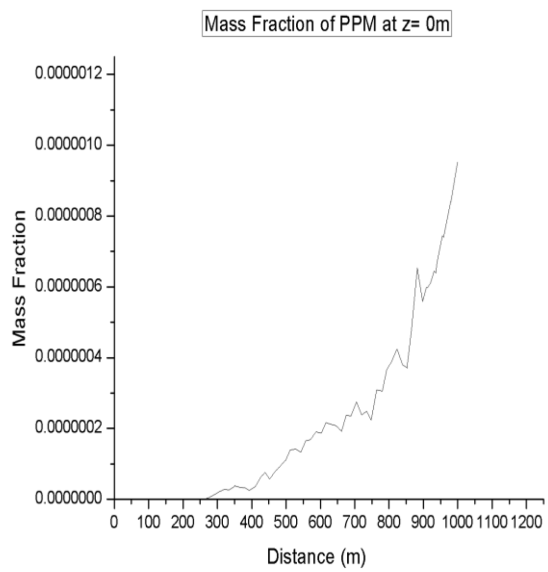
(a)



(b)



(c)

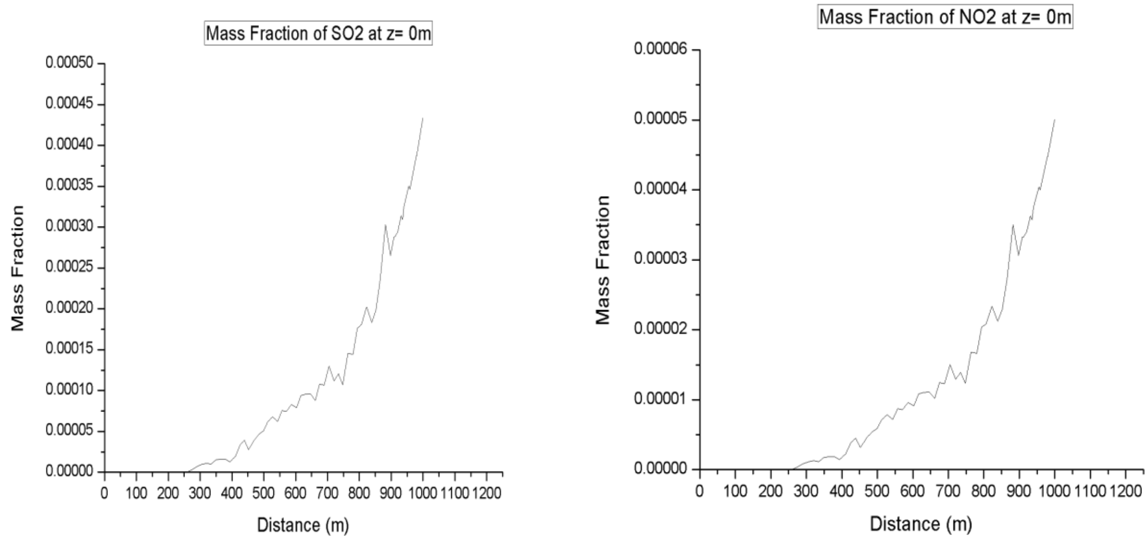


(d)

Figure 5-24 Mass fraction plots for (a) SO_2, (b) NO_2, (c) CO (d) PPM

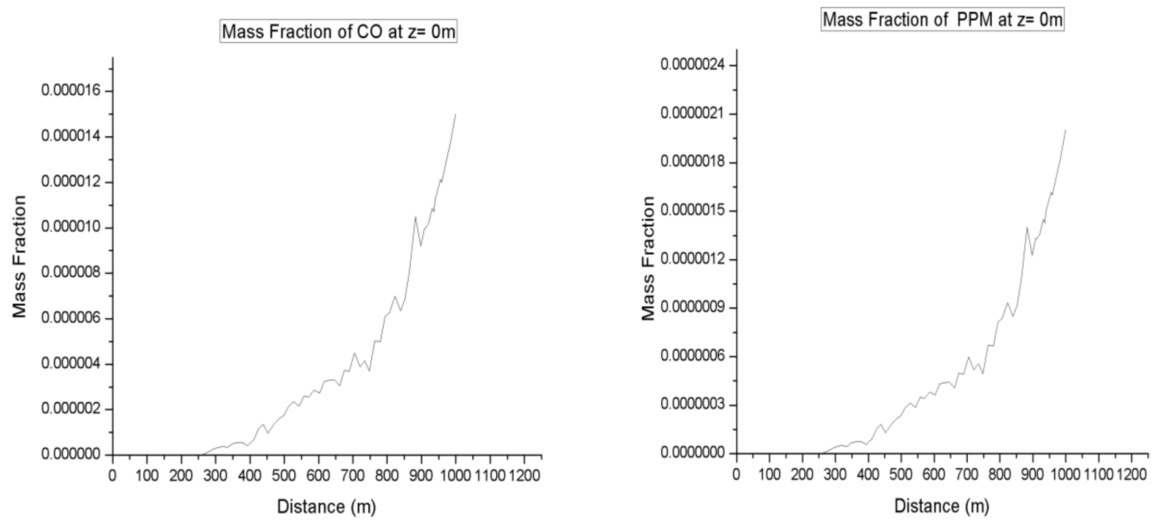
From the figure 5-24, stack velocity is increased to 8m/s. This one is also not recommended by EPA as the concentration of pollutants are still very high.

c) Stack velocity 10m/s at z=0m



(a) (b)

Figure 5-25 Mass fraction plots for (a) SO_2, (b) NO_2,



(c) (d)

Figure 5-26 Mass fraction plots for(c) CO (d) PPM

From the Figure 5-26, On the high wind velocity the concentration of pollutant is increased in ground level. Here the stack velocity is increased to 10m/s as to earlier conditions, the concentration is little bit decreased when to compared stack velocity 5m/s and 8m/s.

CHAPTER 6

CONCLUSION

From the graphs plotted above at different wind velocity conditions and as well as different stack velocity conditions, the pollutant concentration is determined. When the wind velocity is low that is around 1m/s the pollutant concentration on the ground is low and at the high wind velocity (10m/s) the pollutant concentration is increased easily shown in plotting's. As the engineering design is done for worst and best case, the worst condition for any stack design or the plume dispersion is when the wind velocity is very high. In this case the pollutants are dragged off towards the ground level.

To avoid this behaviour stack velocity is to be increased in such a manner that the velocity of wind velocity should be much less than that of stack velocity. To avoid this behaviour we can also have numbers of stack in the industry of different dimensions which can give the different velocities of gases from stack as per required.Finally the best engineering work is done by providing the more turbulence in atmosphere so that there is more diffusion of pollutants and before reaching the ground surface, maximum pollutants should diffuse in environment.

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4 Weil J.C " An updated Gaussian plume model for all stacks". Journal of Air Pollution and control association. ,pp. 815-825, 1984

5 http://yosemite.epa.gov.